Wilson Bulletin 117(1):15–22, 2005

MINIMUM POPULATION SIZE OF MOUNTAIN PLOVERS BREEDING IN WYOMING

REGAN E. PLUMB,[1] FRITZ L. KNOPF,[2,3] AND STANLEY H. ANDERSON[1]

ABSTRACT.—As human disturbance of natural landscapes increases, so does the need for information on declining, threatened, and potentially threatened native species. Proposed listing of the Mountain Plover (*Charadrius montanus*) as threatened under the U.S. Endangered Species Act in 1999 was found unwarranted in 2003, but this species remains of special concern to management agencies and conservation groups. Whereas large concentrations of breeding Mountain Plovers occur in Montana and Colorado, estimates of the numbers of Mountain Plovers in Wyoming have ranged from only 500 to 1,500 individuals and are based largely on conjecture. In 2002, we visited all known breeding locales in the state to define areas of concentrated sightings in the Laramie, Shirley, Washakie, Great Divide, and Big Horn basins. In 2003, we used distance sampling to estimate breeding bird densities in these five areas. We pooled these estimates and applied the resulting density to a minimum occupied range for the Mountain Plover based on the documented sightings and a previously derived home-range size of 56.6 ha ± 21.5 (SD) to generate a minimum population estimate for the state. Average Mountain Plover density was 4.47 ± 0.55 (SE) birds/km^2. We calculated a minimum population estimate of 3,393 birds for Wyoming. The Mountain Plover population breeding in Wyoming appears to contribute substantially to a revised continental population estimate of 11,000 to 14,000 birds. Our approach may have applications to quantifying minimum population status of other uncommon species or species of special conservation concern using current database records, such as those compiled in Natural Heritage Programs at the state level. *Received 28 January 2004, accepted 10 December 2004.*

The Mountain Plover (*Charadrius montanus*) is one of 12 avian species endemic to the grasslands of North America (Mengel 1970). Plovers nest on the shortgrass prairie and shrub-steppe of the western Great Plains and Colorado Plateau, especially in areas used historically by large assemblages of herbivores, such as prairie dogs (*Cynomys* spp.), bison (*Bison bison*), and pronghorns (*Antilocapra americana*; Knopf 1996a). The species winters from north-central California to Arizona, Texas, and northern Mexico.

Once numerous in Colorado and Wyoming and common in western Kansas, South Dakota, and Nebraska, Mountain Plovers began to decline throughout their range early in the 20th century (Laun 1957). They have continued to do so over the past 30 years at a rate approximating 3% per year (Knopf 1996a). As a result, the species' continental breeding range has been significantly reduced. Today the majority of the Mountain Plover's breeding range is restricted to east-central Montana (Skaar 2003), the tablelands of Wyoming (Oakleaf et al. 1992), and eastern Colorado (Andrews and Righter 1992, Kingery 1998). The North American population was recently estimated at 8,000 to 10,000 birds (Knopf 1996a).

In response to evidence of the species' widespread decline, in 1999 the U.S. Fish and Wildlife Service (USFWS) proposed listing the Mountain Plover as threatened under the U.S. Endangered Species Act (ESA) (U.S. Fish and Wildlife Service 1999). The USFWS recently determined that threats to Mountain Plovers and their habitat are not likely to endanger the species in the foreseeable future; thus, the proposed listing of the bird was withdrawn (U.S. Fish and Wildlife Service 2003). Regardless, the Mountain Plover remains as a species of special concern to wildlife and land managers throughout its range.

Although significant breeding populations occur in Montana and Colorado, there is evidence that Wyoming may provide habitats for many breeding Mountain Plovers as well. Survey efforts for plovers in Wyoming, especially in the wake of the recent ESA proposal, have revealed pockets of breeding birds throughout the state, particularly in south-central and eastern Wyoming. The contribution of Moun-

[1] Wyoming Coop. Fish and Wildlife Research Unit, Univ. of Wyoming, Box 3166 Univ. Station, Laramie, WY 82071-3166, USA.

[2] U.S. Geological Survey, Fort Collins Science Center, 2150-C Centre Ave., Fort Collins, CO 80526-8118, USA.

[3] Corresponding author; e-mail: fritz_knopf@usgs.gov

tain Plovers in Wyoming to the continental breeding population is poorly understood, as no reliable statewide population estimate exists. Rough estimates, based largely on conjecture, have ranged from 500 to 1,500 individuals (FLK).

Wunder et al. (2003) recently estimated the size of a similarly undefined population of Mountain Plovers in South Park, (Park County), Colorado. Distance sampling was used to estimate density of breeding plovers, from which a population estimate was extrapolated based on an estimate of occupied habitat. Plovers in South Park occurred at an average density of 7.9 ± 0.9 (SE) birds/km^2 across sampled portions of >80,000 ha of potential habitat. Wunder et al. (2003) concluded that South Park, with an estimated population of >2,300 Mountain Plovers, contributes 15–20% of breeding plovers to the continental population.

Following the success of Wunder et al. (2003) in generating a population estimate in South Park, Colorado, we used distance sampling to generate density estimates of breeding plovers in Wyoming. Although we used distance sampling following Wunder et al. (2003), plovers are much more widely scattered in fragmented habitats across Wyoming compared with their single-county study in Colorado. Our objectives were to (1) compile all documented sightings of Mountain Plovers in Wyoming, (2) visit all locals of documented sightings in 2002 to confirm presence of breeding plovers, (3) conduct surveys of adult plovers at selected areas in 2003, and (4) extrapolate plover densities over the documented breeding range to obtain a minimum population estimate for Mountain Plovers in Wyoming.

METHODS

Documented sightings and statewide reconnaissance.—We collected information about documented locations of Mountain Plovers from state and federal agencies, non-profit and consulting firms, and individuals in Wyoming. We mapped these locations using a Geographic Information System (GIS; ESRI ArcMap 8.3). More than 40 agencies, firms, and individuals contributed to the compiled database representing the documented distribution of Mountain Plovers throughout the state.

Between 12 May and 18 July 2002, we visited all locations in Wyoming with one or more pre-2002 plover sightings and surveyed for presence of Mountain Plovers. We modeled survey protocol after Mountain Plover survey guidelines set forth by the USFWS (U.S. Fish and Wildlife Service 2002). We drove transects along established roads and two-track roads, stopping at 0.4-km intervals to conduct visual scans for plovers. We conducted these scans outside of the vehicle to prompt movement of nesting or resting plovers and maximize their detectability. There was no predetermined length of time for each visual scan; rather, each lasted as long as necessary to cover a 360-degree panorama around the vehicle. Surveys were conducted in the morning between local sunrise and 11:00 MST, and in the afternoon between 16:30 and local sunset to take advantage of horizontal lighting that facilitates detection of plovers. Playback calls were not used. GPS coordinates were taken at the site where each Mountain Plover was first observed. As time allowed, we also surveyed surrounding areas of acceptable habitat from which there were no prior records of plovers; these new sightings were added to the pre-2002 database.

Mountain plover study areas.—We identified five Mountain Plover breeding areas for our study. We stratified these areas into two grassland landscapes and three desert-shrub landscapes. The two grassland landscapes were located in the Laramie and Shirley basins, and the desert-shrub areas were in the Big Horn, Great Divide, and Washakie basins. The five areas were selected based upon accessibility for field personnel and the availability of adequate potential habitat to find a minimum of 40 plovers in a 5-day survey period. Accessibility was limited on many privately owned lands and occasionally vehicle access was limited on public lands.

Study areas in the Laramie and Shirley basins included a portion of the Laramie Plains that extends north and west from Laramie to Medicine Bow and Foote Creek Rim, and the central portion of Shirley Basin, roughly delineated by the two intersections of Wyoming highways 77 and 487 in northeastern Carbon County. These basins represent the highest-elevation grasslands in Wyoming (Knight 1994) and are characterized by interspersed shortand mixed-grass prairie. Shortgrass species include blue grama (*Bouteloua gracilis*) and buffalograss (*Buchloe dactyloides*). Commonly occurring mixed-grass species include needle-and-thread grass (*Stipa comata*), western wheatgrass (*Agropyron smithii*), Sandberg bluegrass (*Poa sandbergii*), threadleaf sedge (*Carex filifolia*), and Indian ricegrass (*Oryzopsis hymenoides*). Several shrub species, including pricklypear cactus (*Opuntia polyacantha*), big sagebrush (*Artemisia tridentata*), budsage (*A. spinescens*), and fourwing saltbush (*Atriplex canescens*) are present. Vegetation communities vary with topography, which ranges from basins and saltpans to elevated plateaus. White-tailed prairie dog (*Cynomys leucurus*) colonies are common and grazing by domestic cattle and pronghorn antelope is pervasive.

The desert-shrub study areas included the Mexican Flats, located west of Dad between Wamsutter and Baggs in the Washakie Basin (Carbon County); a portion of the Great Divide Basin of the Red Desert located south of Cyclone Rim in northern Sweetwater County; and parts of the Big Horn Basin near Cody and Powell (Park County) and Greybull (Big Horn County), particularly Polecat and Chapman benches. These shrubland areas are typified by saline soils and are dominated by greasewood (*Sarcobatus vermiculatus*), shadscale (*Atriplex confertifolia*), fourwing saltbush, and Gardner's saltbush (*A. gardneri*), with winterfat (*Ceratoides lanata*) and pricklypear cactus interspersed. A mosaic is often formed with stands of big sagebrush, saltbush, and greasewood. Mixed-grass species such as western wheatgrass, prairie junegrass (*Koeleria macrantha*), saltgrass (*Distichlis stricta*), and needle-and-thread grass also occur. Community composition is highly dependent on topography, moisture availability, and soil type. Oil and gas development is common, particularly in the Mexican Flats area. The landscape is grazed by domestic sheep and cattle, and by pronghorn. Wild horses are also present in the Washakie and Great Divide basins to the south. White-tailed prairie dog colonies are common throughout.

Population sampling.—During two 10-day surveys in 2003, we surveyed for adult Mountain Plovers at the five study areas defined in 2002. The initial survey occurred in late May, when most breeding birds were on nests. This survey was designed to detect all adult plovers, but especially those that ultimately might nest unsuccessfully and leave the area before the second survey. The second survey occurred in late June to coincide with the chick-rearing phase. The courtship phase in late April and early May was avoided, as survey estimates from that period would be subject to error incurred by detections of migrating birds.

Using an ATV driven at ≤15 km/hr, two observers conducted surveys in each study area along transects with a minimum of 400-m spacing between lines. Plovers move evasively in response to observers on foot, but are more tolerant of slow-moving vehicles; thus, we used an ATV to help ensure detection of birds at their initial location. Each transect began on a road or two-track that ran alongside (narrow strips) or through (large patches) potential plover habitat. We used a random numbers table to determine the distance (from the access road or two-track) driven into each survey area before beginning the transect perpendicular to the access road. We stopped at 0.4-km intervals while surveying and stepped off the ATV. This approach encouraged plovers to stand from their nests, and thus become more visible. All transects were conducted simultaneously by two observers (the double-observer method). Playback calls were not used. We used a laser range finder (Bushnell Yardage Pro Sport, rated to 450 m) to measure the distance to each bird detected and a standard compass to establish the sighting angle from the transect line. We took GPS coordinates on the transect line for each detection. We conducted all sampling between local sunrise and 11:00 and between 16:30 and local sunset to take advantage of horizontal lighting (reducing the effects of plumage counter-shading) and peak activity levels of the birds. We further reduced the sampling window on exceptionally warm days (>30° C) when heat may have reduced activity levels and heat waves may have reduced detectability. Sampling was not conducted when inclement weather or poor lighting threatened to bias probability of detection.

Occupied range.—To define the known occupied range for Mountain Plovers in Wyoming, we combined Mountain Plover locations from the reconnaissance phase in 2002, the distance-sampling phase in 2003, and the locations documented elsewhere. We then overlaid onto the GIS map a lattice with grid size equal to the average home range of the Mountain Plover during brood rearing (56.6 ha). The average home-range size of 56.6 ha was first determined from a study in Weld County, Colorado, by affixing radio transmitters to adult plovers that were attending chicks, and recording daily movements (Knopf and Rupert 1996). Comparable home-range sizes have since been found in other Mountain Plover habitats (Dreitz et al. 2005). We calculated the minimum breeding range of Mountain Plovers in Wyoming by summing the area of the grids in the overlaid lattice that intersected at least one Mountain Plover location. A minimum estimate of population size for Wyoming was based on the 2003 density estimates extrapolated across this minimum breeding range.

Distance analyses.—Using program DISTANCE 3.5 (Thomas et al. 1998), we estimated overall Mountain Plover densities, as well as densities for subsets of grassland and desert-shrub habitats. Distance sampling (Buckland et al. 2001) uses a set of robust models to estimate densities on the basis of measured distances between detected objects and a central point or transect from which the objects were detected. With regard to underlying assumptions, methodological self-assessment, and efficiency in the field, DISTANCE is superior to relative-abundance estimates generated using point counts (Norvell et al. 2003). We treated the distance data as continuous estimates and considered each of six models suggested by Buckland et al. (2001). These models were each composed of a key function or general shape proposed to fit the detection function, and a nonparametric flexible form called a "series expansion" that adjusted the key function. The six models used were the uniform key function with cosine and simple polynomial expansion series, the half-normal key function with cosine and hermite polynomial expansion series, and the hazard-rate key function with cosine and simple polynomial expansion series. The uniform and half-normal key functions are proposed shapes for the detection function, based on *a priori* assumptions about the detection process, whereas the hazard-rate key function is a derived model. We pooled plover sightings recorded from the two 2003 surveys and truncated the largest 10% of sampled distances to reduce error incurred by outliers, as recommended by Buckland et al. (2001). Histograms of the probability of detection were inspected for violation of statistical assumptions. We also considered the six suggested models with stratification by habitat, but stratified models were inferior to unstratified models. Comprehensive explanations of sampling procedure and model selection are given in Buckland et al. (2001) and Burnham and Anderson (2002). Our analytic approach was similar to that used by Wunder et al. (2003) for estimating Mountain Plover densities in Park County, Colorado.

We used Akaike's Information Criterion (AIC) to evaluate the relative strength of each of the 12 models. Because AIC identifies the best of a set of competing models but does not reflect the quality of fit, goodness-of-fit *P*-values were also considered to identify poorly fitting models ($P < 0.05$), should any exist.

To avoid bias incurred by basing parameter estimates on a single model from a set of closely competing models, we used model averaging based on weighted AIC contributions from all 12 models to generate overall density estimates. We estimated density, detection probability, and detection strip half-width for grassland and desert-shrub habitat subsets using model averaging across a set of unstratified models for each habitat.

RESULTS

Inventory and occupied range.—We compiled and mapped >2,000 sightings of Mountain Plovers representing input from >40 sources. These records included 1,347 sightings from the Wyoming Natural History Diversity Database, ~93% and ~57% of which were reported in the last 20 and 10 years, respectively. Virtually all documented sightings from other sources were made within the last 10 years. In 2002, we detected 171 Mountain Plovers on 1,416 km of roads and two-tracks during reconnaissance visits to previously documented sites. We added these 2002 plover locations and 449 new locations recorded during distance sampling in 2003 to the database of documented sightings to map the

TABLE 1. Estimates (SE) of Mountain Plover density, probability of detection, and effective detection strip half-width in grassland and desert-shrub habitats in Wyoming for 2003. Estimates (SE) are derived from DISTANCE 3.5 (Thomas et al. 1998).

	Grassland	Desert-shrub
Birds detected	113	190
Density (plovers/km^2)	5.17 (1.06)	4.23 (0.67)
Detection probability	0.82 (0.13)	0.73 (0.06)
Effective strip half-width (m)	114.70 (18.68)	111.50 (8.6)

known occupied range of Mountain Plovers in Wyoming. The resulting 2,695 compiled observations intersected 1,341 cells in the overlaid 56.6-ha "home range" grid. Therefore, the known occupied range of Mountain Plovers in Wyoming included at least 75,901 (i.e., 1,341 × 56.6) ha of potential habitat. The five study areas for the randomized distance sampling in 2003 overlapped 44% of the known plover locations in Wyoming.

Density and minimum population estimates.—We detected 303 Mountain Plovers during distance sampling along 276 km of transects, roughly divided among the five study areas in 2002. Pooled data across the two 2003 sampling efforts yielded a minimum of 40 detections for each study area. Estimates of density, detection probability, and effective strip half-width were similar for grassland and desert-shrub habitats (Table 1).

Although the hazard-rate key function with cosine and simple polynomial expansion series provided the best fit to the detection function for the unstratified data, all 12 models (six unstratified, six stratified) had $\Delta AIC \leq 5.0$ and goodness-of-fit P-values > 0.1. The overall density estimate, averaged over 12 models, was 4.47 ± 0.55 birds/km^2 (Table 2). In general, the unstratified models showed lower AIC values than the stratified models. Although the poorest fitting unstratified model was as likely as the best stratified model ($\Delta AIC = 2.2$, $w_i = 0.07$ for both), the unstratified models contributed 78% of the weighted estimates. All of the models fit the data well: goodness-of-fit test statistics for the unstratified models (from lowest to highest P-value) ranged from $\chi^2 = 3.56$ ($P = 0.17$) to $\chi^2 = 2.12$ ($P = 0.35$).

Assuming an average home-range size of

TABLE 2. Models used to generate density estimates for Mountain Plovers in five breeding areas in Wyoming for 2003. Both pooled and stratified models are included. Models were run using 303 detections and 10% truncation. Models are ordered by increasing ΔAIC. The AIC weight (w_i), density estimate, and coefficient of variation (CV) are provided for each model.

Model	ΔAIC	AIC weight (w_i)	Density (birds/km^2)	CV
Unstratified				
Hazard rate + cosine	0.0[a]	0.20	4.37	0.12
Hazard rate + simple polynomial	0.0[a]	0.20	4.37	0.12
Uniform + simple polynomial	0.6	0.15	4.60	0.11
Half normal + hermite polynomial	1.7	0.09	4.45	0.15
Half normal + cosine	2.2	0.07	4.53	0.15
Uniform + cosine	2.2	0.07	4.52	0.14
Stratified[b]				
Uniform + simple polynomial	2.2	0.07	4.59	0.10
Hazard rate + simple polynomial	3.0	0.05	4.37	0.12
Hazard rate + cosine	3.0	0.05	4.37	0.12
Half normal + hermite polynomial	4.2	0.02	4.80	0.11
Half normal + cosine	4.2	0.02	4.80	0.11
Uniform + cosine	5.0	0.02	4.55	0.11

[a] AIC = 2692.7

[b] Stratified by habitat type.

56.6 ha (Knopf and Rupert 1996) for Mountain Plovers, the overall density estimate can be applied to the 75,901 ha of geographic range documented in Wyoming to generate a population estimate of 3,393 birds (75,901 ha $\times$ 4.47 birds/km^2). The lower confidence limit for average Mountain Plover home range (35.1 ha) can be used to generate a more conservative estimate of 2,270 birds. Because the occupied range for Mountain Plovers in Wyoming is surely underestimated, the upper confidence limit for home range (78.1 ha) may be a better approximation, yielding a population estimate of 4,427 birds.

DISCUSSION

Generating reasonable population estimates is particularly challenging for low-density species of conservation concern, such as the Mountain Plover. Distance sampling is a powerful tool for developing such estimates given the time and resources to collect adequate data. Buckland et al. (2001) recommend a sample size of at least 60–80 detections, but admit that suitable precision may require several hundred detections. Reasonable sample sizes were only achieved in this study by focusing sampling efforts on areas with relatively high concentrations of recent (<20 years) Mountain Plover sightings. Those areas occur either where plovers are most visible or where people look for plovers. Much (perhaps most) of the potential plover habitat in Wyoming has never been surveyed for the species.

The validity of the extrapolated minimum population estimates described here largely rests on the accuracy of estimates of occupied range and average home-range size for Mountain Plovers. Given the impracticality (scale of effort, access to private lands) of surveying all potential Mountain Plover habitat in Wyoming, we initially considered a habitat-based model that employed satellite imagery for estimating the occupied range of the species. This model was deemed unsuitable because Mountain Plovers in Wyoming frequently occupy habitat patches of such small size or subtle distinction, relative to the dominant cover type, that suitable patches cannot be distinguished remotely. Therefore, we compiled documented sightings of plovers collected by field biologists to represent a best-available approximation of a statewide survey for Mountain Plovers. It is likely that many breeding locales are still unknown and unsurveyed, thus affirming the *minimum* nature of our estimates. The second assumption, that the home-range size from Weld County, Colorado, can be applied to other areas, has recently been confirmed by studies that revealed comparable home-range size in dissimilar habitats at various locales (Dreitz et al. 2005). Finally, we assumed that densities in sampled areas are representative of densities throughout the species' occupied range. This latter assumption was supported by the similar plover densities calculated in grassland versus desert-shrub habitats.

We did not need to assume plover occupancy of all pre-2003 grid cells in our extrapolation of calculated plover density across the pre-2003 sightings template. Distance sampling in the 2003 survey areas was independent of both the pre-2003 cell distribution and any knowledge of statewide plover-density patterns. The 2003 distance-sampling transects (covering 44% of the pre-2003 area) would have been as likely to sample 2003-occupied as 2003-unoccupied cells in the pre-2003 database. Thus, the distance sampling effort in 2003 included "occupancy" information relative to the earlier sightings.

Plover densities were comparable across habitat types. The overall density in grassland habitats was slightly higher (5.17 birds/km^2) than in desert-shrub habitats (4.23 birds/km^2), with considerable overlap between confidence intervals. Eighty-six percent of the desert-shrub confidence interval was contained by the grassland confidence interval. The congruence of density estimates across habitats supports the calculation of a pooled density estimate to represent plover habitats statewide.

The average density of Mountain Plovers in documented breeding areas in Wyoming (4.47 $\pm$ 0.55 birds/km^2) is somewhat lower than most density estimates within the species' breeding range. Finzel (1964) reported 6.2 birds/km^2 near Laramie and 12.3 birds/km^2 near Cheyenne, Wyoming. Wunder et al. (2003) reported densities of 6.0–9.0 birds/km^2 for South Park, Colorado, and Knopf (1996a) reported densities of up to 4.7 birds/km^2 on Pawnee National Grassland in Colorado and 1.3–6.8 bird/km^2 on prairie dog towns in Montana. Graul and Webster (1976) estimated plover densities at 8.0 birds/km^2 in areas of Wyoming and Montana.

Our calculated potential habitat of 759 km^2 for Mountain Plovers in Wyoming is an underestimation. Most private lands have never been surveyed for plovers. These lands are primarily used for grazing, a major component of plover habitats throughout the year (Knopf 1996a, Wunder and Knopf 2003). The only desert regions of Wyoming being surveyed consistently at present are those targeted for oil and gas leasing or development. We also note that whereas the most productive grazing lands in Wyoming are in private ownership, our surveys were conducted on publicly owned, less productive landscapes. Mountain Plover densities are likely higher in the privately owned and more productive landscapes, and those landscapes are under-represented in our potential-habitat database.

Considering that the recent global population estimate for Mountain Plovers is 8,000 to 10,000 individuals (Knopf 1996a), and that Wyoming's conservative estimate of 3,393 plovers may not include birds that (1) occupy large expanses at low densities, (2) occur in isolated small patches of habitat (e.g., historic buffalo wallows; FLK pers. obs.), or (3) breed at undiscovered spots, Wyoming's Mountain Plovers appear to contribute substantially to a revised continental population estimate of 11,000 to 14,000 birds. Furthermore, management strategies for Mountain Plover habitat in Wyoming often emulate the historical ecological drivers (e.g., drought and grazing; Knopf and Samson 1997) to a greater extent than do practices in neighboring states where cultivation and urbanization are more widespread. When rangeland conversion to row cropping does occur in Wyoming, it is generally to a lesser extent than in other states within the plover's range. Between 1982 and 1997, more than three times as much rangeland within the occupied breeding range of Mountain Plovers was converted in Montana than in Wyoming; 12 times as much potential habitat was converted in Colorado (U.S. Fish and Wildlife Service 2003). Wyoming's population of Mountain Plovers and relatively intact expanses of grazed rangeland may become increasingly important for the species as urban and agricultural development continues in contiguous states.

Mountain Plovers, like many species of conservation interest, occur in low densities and in a variety of landscapes. Plovers often are not detected in general biotic surveys due to their relative inconspicuousness. Our study took advantage of an existing database of mostly casual observations to focus intensive surveys for estimating population status in Wyoming. This approach may be useful for quantifying minimum population size of other species of conservation concern. Existing database records, such as those available from state Natural Heritage Programs, may be particularly useful.

ACKNOWLEDGMENTS

We are especially grateful to V. L. Sepulveda for invaluable field assistance spanning two seasons. Thanks to M. B. Wunder for assistance with program DISTANCE, and to the U.S. Fish and Wildlife Service, U.S. Geological Survey, U.S. Bureau of Land Management, and the Wyoming Game and Fish Department for funding assistance. B. A. Banulis, S. R. Mohren, N. P. Nibbelink, J. C. Oakleaf, and S. J. Slater provided critical GIS support. Field biologists G. P. Beauvais, T. W. Byer, L. D. Hayden-Wing, L. G. Keith, T. Maechtle, S. H. Nicholoff, R. J. Oakleaf, M. S. Reid, D. F. Saville, and L. Van Fleet deserve recognition. S. J. Dinsmore provided helpful comments on the manuscript. We are indebted to landowners in the Laramie and Shirley basins for providing access to their private lands. We acknowledge R. L. Leachman for his tireless years of effort to secure the future of Mountain Plovers.

LITERATURE CITED

Andrews, R. and R. Righter. 1992. Colorado birds: a reference to their distribution and habitat. Denver Museum of Natural History, Denver, Colorado.

Buckland, S. T., D. R. Anderson, K. P. Burnham, J. L. Laake, D. L. Borchers, and L. Thomas. 2001. Introduction to distance sampling. Oxford University Press, New York.

Burnham, K. P. and D. R. Anderson. 2002. Model selection and multi-model inference: a practical information-theoretic approach. Springer-Verlag, New York.

Dreitz, V. L., M. B. Wunder, and F. L. Knopf. 2005. Movements and home ranges of Mountain Plovers raising broods in three Colorado landscapes. Wilson Bulletin, in press.

Finzel, J. E. 1964. Avian populations of four herbaceous communities in southeastern Wyoming. Condor 66:496–510.

Graul, W. D. and L. E. Webster. 1976. Breeding status of the Mountain Plover. Condor 78:265–267.

KINGERY, H. E. (ED.). 1998. Colorado breeding bird atlas. Colorado Bird Atlas Partnership and Colorado Division of Wildlife, Denver, Colorado.

KNIGHT, D. H. 1994. Mountains and plains: the ecology of Wyoming landscapes. Yale University Press, New Haven, Connecticut.

KNOPF, F. L. 1996a. Mountain Plover (*Charadrius montanus*). The Birds of North America, no. 211.

KNOPF, F. L. 1996b. Prairie legacies—birds. Pages 135–148 *in* Prairie conservation: preserving North America's most endangered ecosystem (F. B. Samson and F. L. Knopf, Eds.). Island Press, Covelo, California.

KNOPF, F. L. AND J. R. RUPERT. 1996. Reproduction and movements of Mountain Plovers breeding in Colorado. Wilson Bulletin 108:28–35.

KNOPF, F. L. AND F. B. SAMSON. 1997. Conservation of grassland vertebrates. Ecological Studies 125: 273–289.

LAUN, H. C. 1957. A life history study of the Mountain Plover, *Eupoda montana*, Townsend, on the Laramie Plains, Albany County, Wyoming. M.Sc. thesis, University of Wyoming, Laramie.

MENGEL, R. M. 1970. The North American central plains as an isolating agent in bird speciation. Pages 280–340 *in* Pleistocene and recent environments of the Central Great Plains (W. Dort and J. K. Jones, Eds.). University of Kansas Press, Lawrence.

NORVELL, R. E., F. P. HOWE, AND J. R. PARRISH. 2003. A seven-year comparison of relative-abundance and distance-sampling methods. Auk 120:1013–1028.

OAKLEAF, B., B. LUCE, S. RITTER, AND A. CEROVSKI, (EDS.). 1992. Wyoming bird and mammal atlas. Wyoming Game Fish Department, Lander.

SKAAR, P. D. 2003. P. D. Skaar's Montana bird distribution, 6th ed. Montana Natural Heritage Program, Helena.

THOMAS, L., J. L. LAAKE, J. F. DERRY, S. T. BUCKLAND, D. L. BORCHERS, D. R. ANDERSON, K. P. BURNHAM, ET AL. 1998. Distance 3.5, release 6. Research Unit for Wildlife Population Assessment, University of St. Andrews, United Kingdom.

U.S. FISH AND WILDLIFE SERVICE. 1999. Endangered and threatened wildlife and plants: proposed threatened status for the Mountain Plover. Federal Register: 64(30):7587–7601.

U.S. FISH AND WILDLIFE SERVICE. 2002. Mountain Plover survey guidelines, http://montanafieldoffice.fws.gov/Endangered_Species/Survey_Guidelines/Mountain_Plover_Survey_Guidelines.pdf (accessed March 2002).

U.S. FISH AND WILDLIFE SERVICE. 2003. Endangered and threatened wildlife and plants: withdrawal of the proposed rule to list the Mountain Plover as threatened. Federal Register 68(174):53083–53101.

WUNDER, M. B. AND F. L. KNOPF. 2003. The Imperial Valley of California is critical to wintering Mountain Plovers. Journal of Field Ornithology 74:74–80.

WUNDER, M. B., F. L. KNOPF, AND C. A. PAGUE. 2003. The high-elevation population of Mountain Plovers in Colorado. Condor 105:654–662.